A Simple Digital Power Meter

*Part 1, by Dave Roberts, G8KBB**

ONE OF THE basic requirements we face is the measurement of RF power. This article describes a simple to build, yet potentially accurate digital power meter. It is designed to operate as an inline power meter and displays the results on a 16 digit LCD display. It measures, in one range, power from 100nW to 100W (9 orders of magnitude) covering all HF bands up to 145MHz. It is usable, with correction, to 432MHz.

The meter comprises two separate parts, an RF unit and a display unit. The interface between them is a DC voltage across a specified range. It is therefore possible to re-use either part in different ways - for example, the RF unit may be built without the digital display, either to drive an exiting meter or as an RF sniffer.

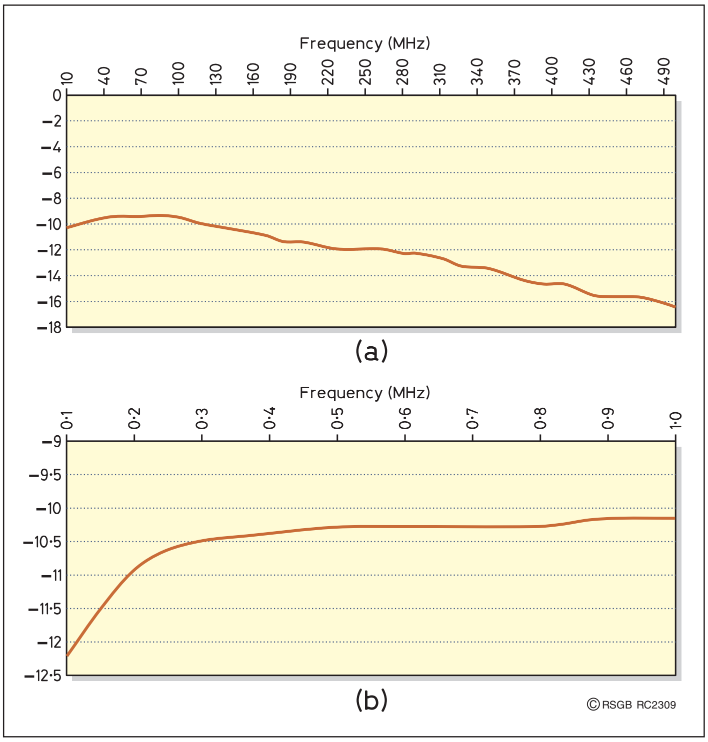

Fig 1: Frequency response from (a) 10 to 500MHz, (b) 100kHz to 1MHz, for the power meter.

SPECIFICATION

THE UNIT OPERATES over a 90dB range from 100kHz to 500MHz and displays its results on the LCD display in both dBm and watts. The power source is 9 - 15V DC, consuming about 12mA. Subject to calibration - and that is a big assumption - the meter is accurate to within ±1dB from 200kHz to about 175MHz, and the deviation from log law is ±0.5dB. The frequency response is shown in **Fig 1** and **Fig 2**. At 432MHz it reads about 5dB low. Please note that Fig 2 was drawn from an early prototype, and the low signal performance should be slightly better than this. The display shows the effect of the 14dB cells in the AD8307. The kink near 10dBm is probably a measurement error.

The RF unit is based on the excellent Analog Devices log detector chip, the AD8307 [1] (**Fig 3**). The display is based on a single chip PIC processor, the PIC14C000 Mixed Mode Controller, which requires programming. This can be achieved via a PC bi-directional parallel printer port, using a small additional circuit if a programmer that will handle the 14000 is not available.

In the unit to be described, the range of the device is -40dBm (100nW) to +50dBm (100W), but the design can be easily modified for different ranges, as will be detailed later.

The digital display is not ideal for making adjustments to a circuit. If you wish to also use it for that, then put a small panel meter with suitable series resistor across the output of the RF unit. If you don't need the display, just build the RF unit with an analogue meter.

THEORY OF OPERATION - RF UNIT

THE RF UNIT is outlined in **Fig 4**, with the complete circuit shown in **Fig 5**.

It is in reality a lie to call it a power meter; it is a voltmeter calibrated to give a DC voltage that corresponds to the RF voltage at its input. This is scaled to read in a calibrated manner when terminated in 50Ω.

The RF voltage at the input is sensed at a BNC socket. Typically, this would be directly connected via a BNC T-piece to a transmission line, as the mismatch at the frequencies of interest here is not significant. The T piece is inserted into a correctly terminated coax transmission line that carries the signal to be measured. The voltage is AC coupled (hence the low frequency limit of the circuit) via a resistive attenuator into the AD8307 chip. This is described further below, but in essence it delivers a DC current corresponding to the RF input. This current is converted into a voltage by passing it through a terminating resistor and is then buffered and amplified to give the RF unit output voltage. With the values shown in Fig 5, the output voltage gives a range of 0 to 5 V with a 5V supply, giving 2.5V for 0dBm input, changing by 0.5 V per 10dB change in input. The noise floor of the AD8307 gives a minimum signal of about 0.5V (-40 dBm) and the upper limit is 5V (+50 dBm). If you plan to use the digital display unit, then the value of R7 must be changed from 33K to 11K. This gives a range of 0V to 3V, which matches the PIC processor ADC range. A reading of 0dBm will then give 1.5V output, changing

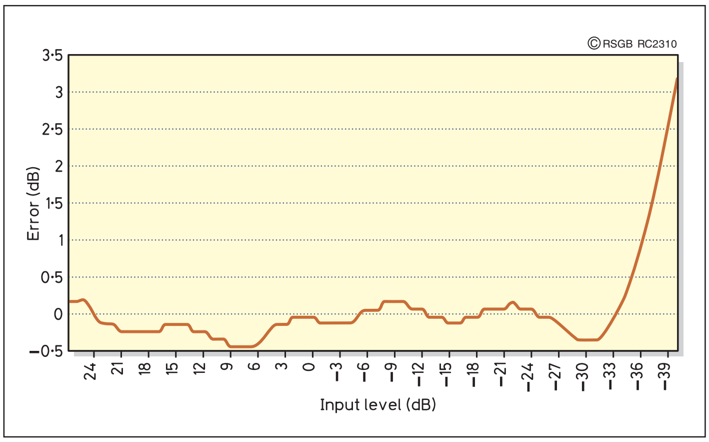

Fig 2: Log amp error plot. The display shows the effect of the 14dB cells in the AD8307.

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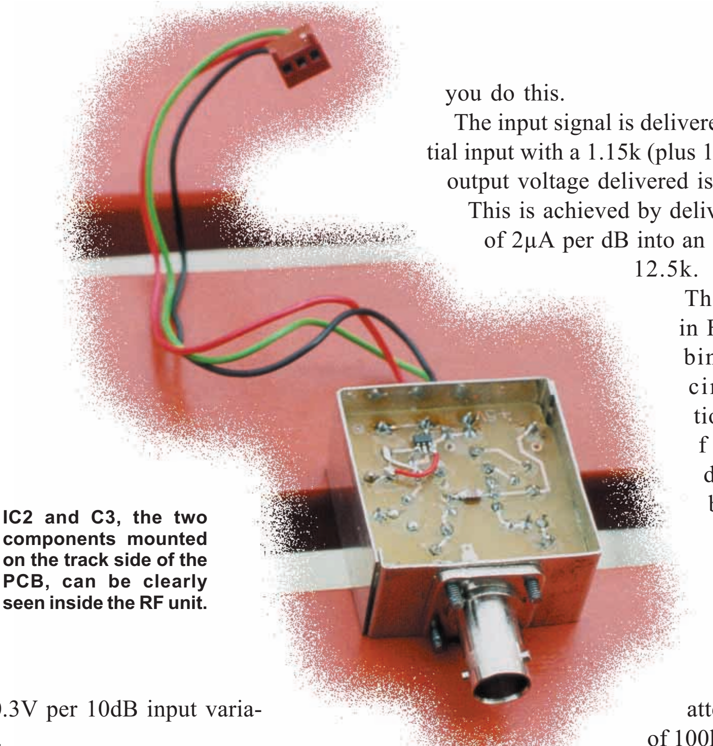


IC2 and C3, the two components mounted on the track side of the PCB, can be clearly seen inside the RF unit.

by 0.3V per 10dB input variation.

The AD8307 is specified over the range DC to 500MHz. A block diagram is reproduced from its datasheet [1] in Fig 3. The logamp has a 92dB range to ±3dB conformance and is ±1dB over an 88dB range. It is important to bear this in mind when using the unit. The display shows readings to 0.1dB - but purely to aid seeing small relative differences - you cannot believe their absolute accuracy - that is *at best* ±1dB. The INT and OFS inputs allow adjustment of the operation of the device. INT is designed to allow the intercept point to be adjusted - essentially an adjustment of the 'no signal' output of the device. OFS is connected to the offset null circuits of the device. If you think about it, a DC coupled log amp operating down to microvolts will suffer from DC offsets in the amplifiers. To compensate for this, the chip includes an automatic offset null circuit that corrects continually for small errors. The OFS pin connects to the feedback loop within this circuit. In this application it is unused, as its main purpose is to control the low frequency response of the device. Low frequency signals will tend to be cancelled by the offset null circuit. This is in part the reason for the low frequency tail off of the unit below 1MHz. If it is desired to extend this low frequency response, a small (eg 100pF) capacitor should be connected from OFS to ground. This will augment the on-chip capacitor. The input coupling capacitors would likewise have to be increased. Keep the wires short if you do this.

The input signal is delivered to a differential input with a 1.15k (plus 1.4pF) load. The output voltage delivered is 25mV per dB. This is achieved by delivering a current of 2µA per dB into an internal load of 12.5k.

The circuit shown in Fig 5 is a combination of two circuit suggestions in the manufacturer's datasheet. The basic method of operation, as suggested by Analog Devices, is a 1kW power meter using an input attenuator resistor of 100k. I found it difficult to achieve adequate performance with this impedance, plus I am not interested in high power, so I settled for a 33k input resistor and a 100W range. If you wish to create a 1kW meter, change the resistor to 100k, but you will need to be careful about construction. The PIC software allows it to be configured for full scale ranges of 1kW, 100W, 10W or 1W. Incidentally, lower values of resistance, especially in R2, would improve frequency response. You might care to consider using values of 15k and 390Ω respectively. This would improve high frequency response at the risk of heating in R1 at high power levels. A 15k resistor would dissipate 1/3W at 100W, assuming the line is properly terminated. If not, it could be much higher.

IC2 is an output buffer formed of a rail-to-rail 5V op-amp. This is a fairly cheap surface mount device available from Farnell. If you don't fancy surface mount, then the board is easy to retrack for a DIL amplifier using a slightly larger box.

RV2 allows roughly 3dB adjustment in the intercept point (ie the absolute level of output to input) and RV1 allows similar adjustment to the slope. This is achieved by altering the load resistor, into which the current mirror delivers its signal.

The output lead from the op-amp should ideally be decoupled. If this is done through a standard 1nF feed-through capacitor, then there is a chance that the op-amp may become unstable. The phase margin of the op-amp in the configuration shown with a 1nF capacitor would be about 10°, but feed-through capacitors are not the most accurate items in the world. They typically have a tolerance of -0% to +200%. This means that a 1nF capacitor may be 3nF. Adequate stability at this level is not guaranteed. Therefore, you should use a feed-through decoupling capacitor of 100pF or 470pF if available. If not, use an insulated lead-through. If you do use a 1nF feed-through and the op-amp is unstable, try a 1k resistor in parallel with the output, which should increase phase margin by about 20°.

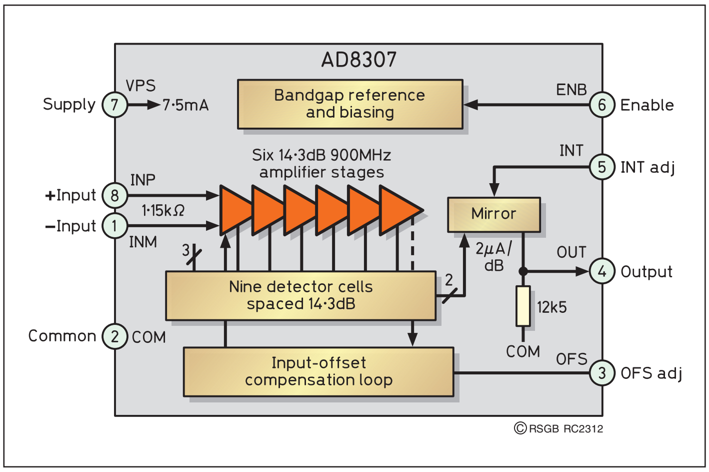


Fig 3: Block diagram of the AD8307.

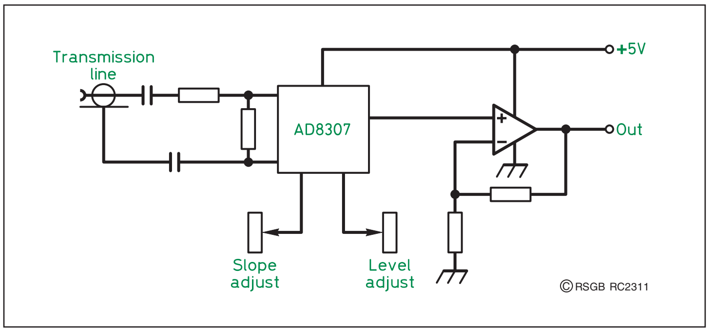


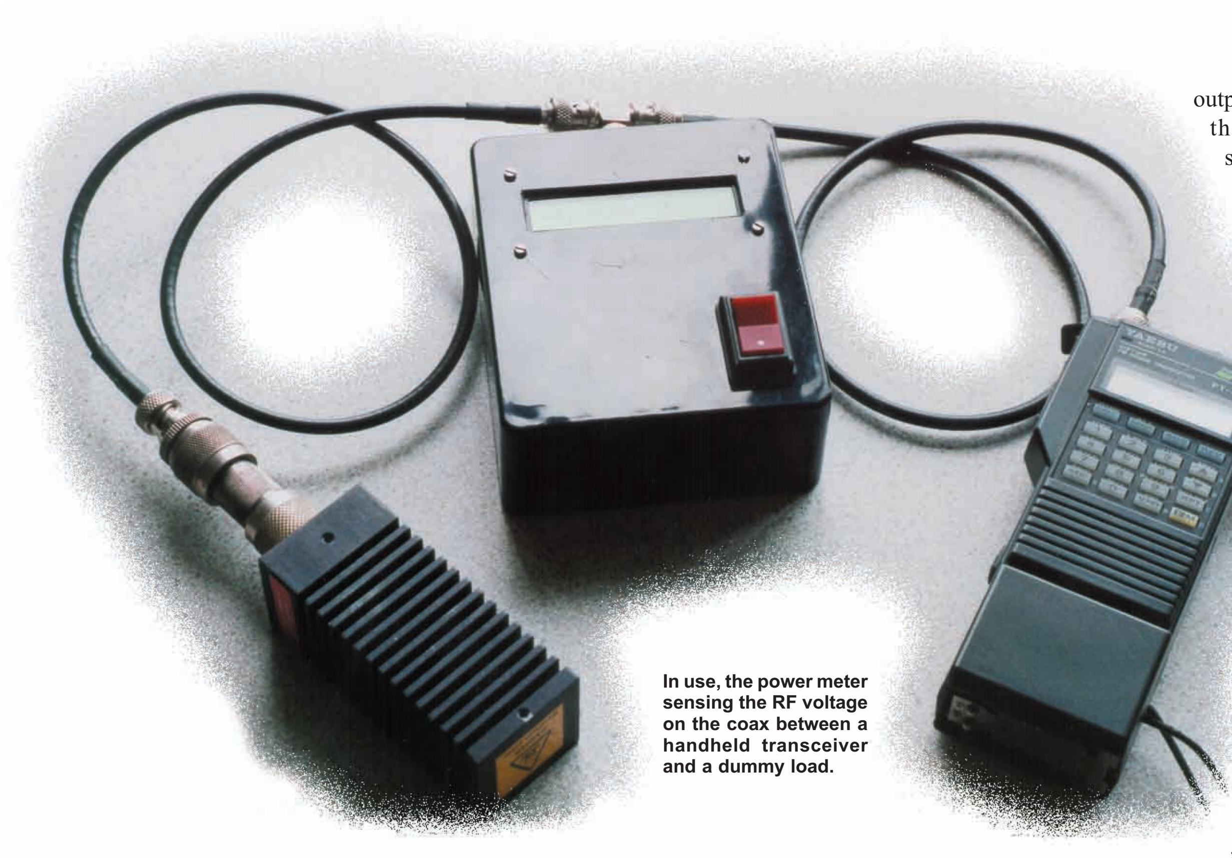
Fig 4: RF unit outline.

HOW ACCURATE IS IT REALLY?

BEING HONEST, you will not see accuracy to within 1dB. There are a number of reasons for this. Firstly, the AD8307 has its own inaccuracies. Secondly, the unit is frequency sensitive. Thirdly, the equipment against which it is calibrated will have an error. Finally, as it measures voltage not power, non-50Ω systems (for example VSWR not 1:1) will introduce errors.

Take an example. If the AD8307 is at the extreme of its specification (1dB out), the signal generator against which it was calibrated is out by 1.5dB and you measure a signal on a line with a VSWR of 1.5 : 1, the error could be as much as 4.2dB.

In practice it will not be that



In use, the power meter sensing the RF voltage on the coax between a handheld transceiver and a dummy load.

far out, but do exercise caution. The most significant place where care should be taken is in calibration. If you have a good oscilloscope, use it to check the signal generator level. If you have access to a second signal generator, use it to check the first as well.

With care it will measure reasonably accurately, but remember the display resolution is outrageously fine compared to the accuracy.

One final source of error. If the signal is modulated two things will happen. First, the low pass filter in the AD8307 will show an asymmetry to the modulation, due to the fact that it is charged from a current mirror and discharged by a resistor. Secondly, and more significantly, the ADC used in the PIC14000 will trigger early on the dips in the RF signal. This will cause the meter to read low. The signal is low pass filtered and the effect is small, but it is still noticeable. If this causes problems you might care to consider better filtering.

CONSTRUCTION OF THE RF UNIT

THE PROTOTYPE was built into a standard 37mm x 37mm tinplate box. It comprises a double-sided PCB used to provide a ground plane plus one signal layer, the artwork being shown in **Fig 6** with the component placement in **Fig 7a** and **Fig 7b**. The AD8307 and op-amp may be obtained from Farnell. The op-amp is cheap (about 35p), but the AD8307 is expensive (just over £10). The board is carefully cut down to size so that it will push-fit into the box. The BNC connector is bolted to one end, so having cut the board to size, carefully drill the side of the tinplate box and bolt the connector to it. The board is fitted just below the socket, so that the pin protrudes about 5mm above the ground plane, but to achieve this it will probably be necessary to file a small recess into the edge of the PCB to allow for the rim of the socket.

When this has been done, drill the PCB. Don't forget to clear all non-ground holes on the ground plane side so they will not short to earth, but be careful not to clear any holes that need to solder direct to the ground plane - especially the AD8307 ground pin. Before soldering the PCB in, though, don't forget to drill two holes (one for DC supply, one for output signal), in the face of the box opposite the socket, high above the ground plane and above the PCB connection pads. The power lead should be run through a 1nF feed-through capacitor. The signal will exit either through a feed-through capacitor or an insulated connector .

The PCB may now be seam soldered to the tinplate box. When it has cooled, check that the lids can still be fitted top and bottom of the box. It is worth making sure that it is going to fit correctly *before* you solder it!

Now assemble the components on the top of the board. Leave the input attenuator resistor and trim pots until last. The AD8307 must *not* be mounted into a socket (yes, it is expensive, but resist the urge). The ground pin of the log amp plus all other earth connections solder direct to the surface of the ground plane. Turn the unit over and mount the two surface mount components. One is the AD8307 decoupling capacitor the other the op-amp. The decoupling capacitor is mounted directly between the power and earth pins of the AD8307. There is a simple way to mount SM devices. Use a cocktail stick to position the device. Cut a small piece of fine solder

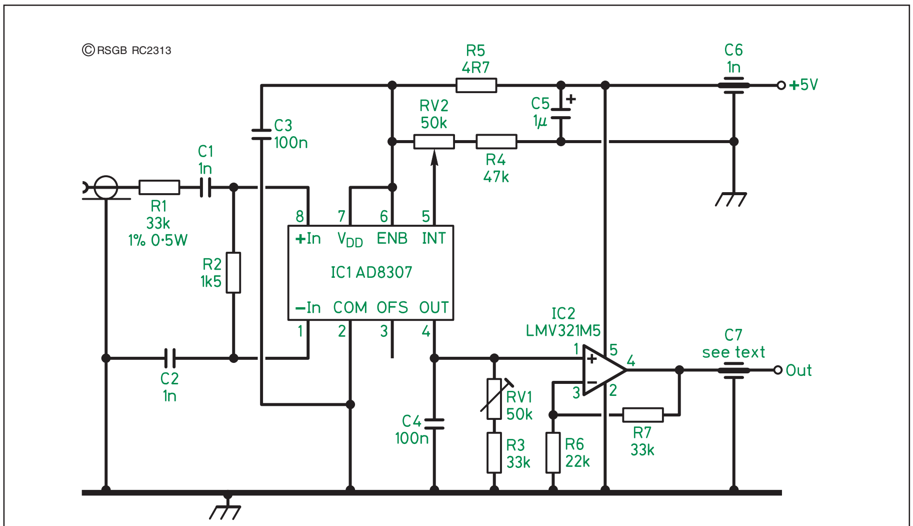


Fig 5: RF unit circuit diagram. See the text on page 16 regarding of the value of R7. It should be 11k if the unit is used with the digital display. See the text on page 17 regarding C7 and instability.

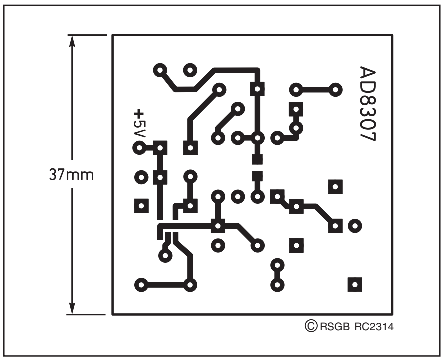
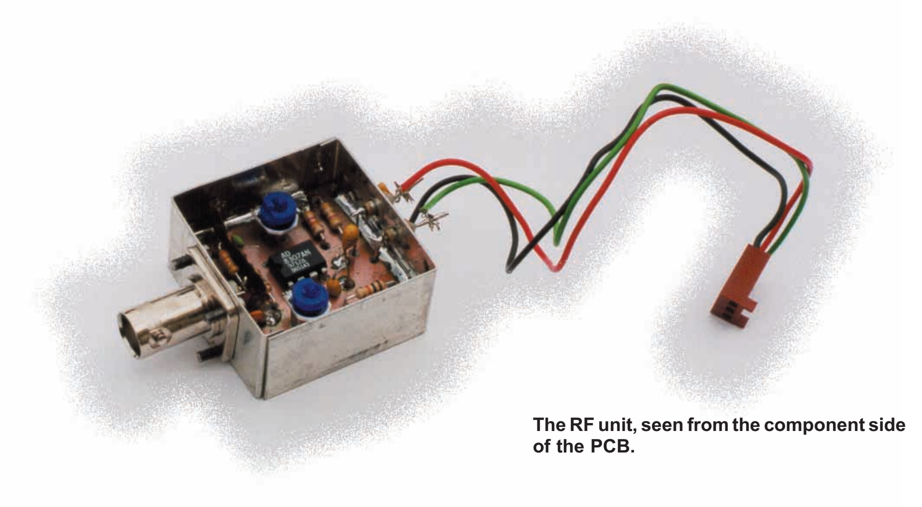


Fig 6: RF unit PCB track layout.



The RF unit, seen from the component side of the PCB.

(1-2mm long) and place it next to the first pin to be soldered. Now hold the device steady with the cocktail stick whilst touching the tip of a fine soldering iron to the pad, solder and pin. The result should be a clean joint. Now solder the other pins similarly. The chip capacitor is an 0805 size device, the op amp an SOT23-5.

Finally, mount the input attenuator resistor between the pin of the BNC and the PCB. You may have to cut its length down to get it to fit. I also found it beneficial to put a small piece of copper foil around the resistor as a screen. A small L shaped piece is soldered to the side of the box next to the socket and to the side and to the ground plane. Don't get too fussy about this - just tack it into place with the iron but keep it clear of the BNC pin as far as possible.

Don't forget to connect the power and output signals.

ALIGNING THE RF UNIT

THE UNIT IS designed to deliver a calibrated output covering 0 to 5V, or 3V if it is to be used with the digital display. To achieve this, it is necessary to align it. There are two adjustments to make, and the adjustment is largely iterative. In the following text, with the value of R7 set to 11k as detailed above, the voltages below will be different (as shown below in parentheses).

RV2 adjusts the 'level' of the input and RV1 adjusts the 'slope'. In order to align it, you will need an RF source at a known level of 0dBm. This is best achieved from a signal generator, and a stepped attenuator will also be needed. Connect a BNC T piece to the input socket, connect one side to the signal source through a stepped attenuator and the other side to a 50Ω load. Connect a digital voltmeter to the output and apply 5V DC to the power pin. It should draw just under 10mA. Check the calibration of the signal generator if at all possible.

What needs to happen next is simple, iterative and frustrating. You must adjust the two variable resistors for correct slope and zero point. First switch off the signal source but leave the dummy load connected. Adjust RV2 so that the DC voltage is about 0.45V (0.3V for LCD display version). Now apply 0dBm and note the input voltage, which should be roughly 2.5V (or 1.5V). Drop the input signal by 10dB and the reading should drop by 0.5V (0.3V). Adjust RV1 slightly until it does. Now switch back to 0dBm and adjust RV2 for 2.5V (1.5V). Repeat until you have a DC output of 2.5V (1.5V) for 0dBm input that changes by 1V (0.6V) for every 20dB change in signal level into the load.

Having achieved this, it is now worthwhile checking the linearity of the response over as wide a range as you have a known signal for and check the accuracy across as much of the frequency range as you are interested in. Note that you can expect a small dip at high frequency as the AD8307, whilst good, is not perfect and the 1.5pF input capacitance causes a roll-off. One thing to note in the non-digital display version. The unit will deliver 5V for a full scale input from a rail-to-rail op-amp - but it needs a 5V supply. Give it 4.9 volts and it will top out at 2dB less than you were expecting. If necessary, set the power supply slightly higher, such as 5.25V. With a full scale output of 3V for the LCD display version, this is not a problem.

You now have a working power meter that may either be used on its own or connected to the display unit. If you connect an aerial or similar pickup without a 50Ω load, it also makes a neat RF sniffer or voltmeter.

REFERENCE

[1] AD8307 datasheet, available from the Analog Devices web site, at www.microchip2 .com

♦

To be continued...

COMPONENTS

Resistors (all 5% ¼W unless otherwise stated)

R1	33k 1% 0.5W
R2	1k5
R3	33k 1% or 11k 1% - see text
R4	47k
R5	4R7
R6	22k 1%
RV1, RV2	50K sub min trimpot

Capacitors

C1, C2	1nF ceramic
C3	0.1µF 0805 SM chip ceramic
C4	0.1µF ceramic
C5	1µF 16V tantalum
C6	1000pF feedthrough
C7	100 or 470pF feedthrough

Semiconductors

IC1	AD8307 (8-pin DIL) [Farnell 284-040]
IC2	LMV321M5 (sot23-5) [Farnell 101-590]

Miscellaneous

BNC socket
37x37mm tinplate box

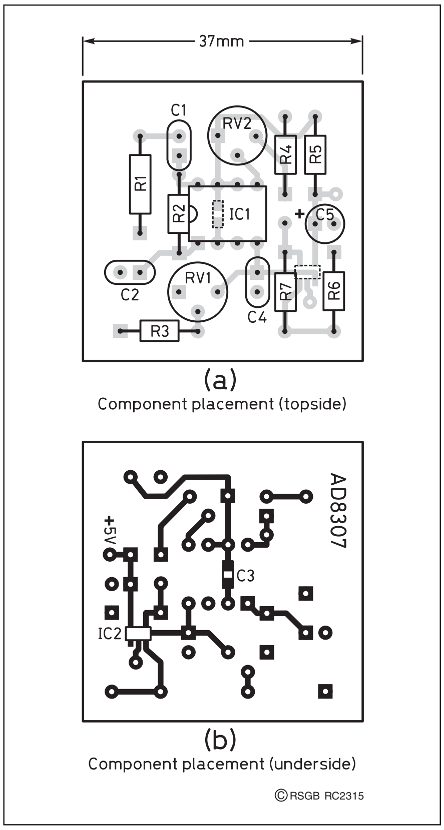


Fig 7: Component placement for (a) topside, and (b) underside of the PCB.

A Simple Digital Power Meter

*Concluding part, by Dave Roberts, G8KBB**

IN PART ONE the RF section of the project was described. It can be used stand-alone, either as an RF sniffer or as a power meter with a conventional meter movement. Alternatively, it can be connected to the LCD unit described here, to produce a power meter with digital readout.

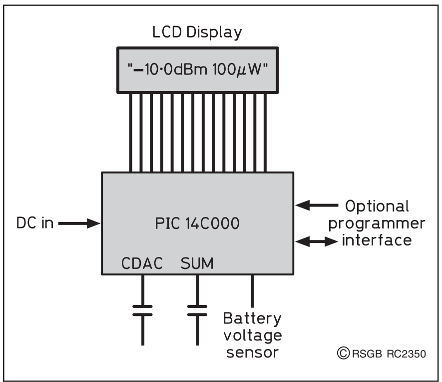


Fig 8: Block diagram of the display unit.

THE DIGITAL DISPLAY

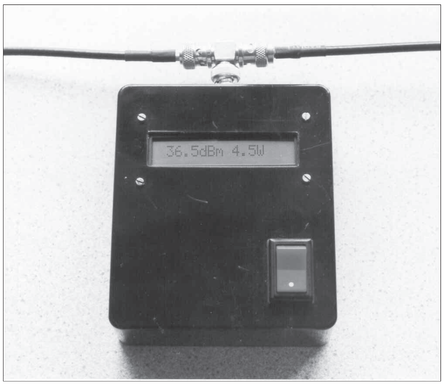
A BLOCK DIAGRAM of the digital display unit is shown in **Fig 8** and the circuit is shown in **Fig 9**. The input voltage is scaled to a range of 0 to 3V, to match the PIC ADC, and fed into one of the PIC Analogue-Digital Converter ports. The ADC is capable of reading to between 8 and 16 bits resolution by timing the period needed to charge a capacitor to a given voltage from a stable current source. This is converted into an accurate voltage reading by performing trial conversions on a zero input and a known bandgap reference input. Note that the input must be driven by a low impedance source for correct operation. This is achieved by the op-amp in the RF unit. The 100k resistor connecting the input to ground is to stop it floating when disconnected (with no signal, the input will not sit at 0V but at a voltage slightly higher). Ground it and the display should show -50dBm. For each displayed value, 8 samples are taken and the average is displayed.

The software derives a reading internally in volts in floating point format. This is converted to a notion of dBm by subtracting 1.5V and multiplying by a constant of 333.333. The result is an integer reading of dBm times 10 from -400 to +500 (-40.0 to +50.0 dBm). This is displayed on the LCD. The reading is also converted into watts, by performing a log table lookup and scaling the reading. It therefore displays power in dBm, followed by watts. The wattage reading is to two significant figures with decimal point or trailing zero as needed followed by the characters 'nW', 'µW', 'mW' 'W' or 'kW'.

The software is a crib from one of the Microchip application notes [4]. In this, a design for a battery monitor is given that measures voltage and current and sends the resulting readings serially as RS232 data. In this circuit, the RS232 module was removed and replaced by the power conversion and LCD display code. The bulk of the code is the original from Microchip.

The software also performs two other functions. First, it measures the voltage on a second analogue input. It is designed to be connected to a resistive attenuator, as shown in the full circuit diagram. This is scaled by the software, so that when the input voltage falls below 8V DC, the power display will be replaced by 'BATTERY LOW'. In order to allow this feature to be switched off, the display reverts to power measurement if the voltage is below 2V. Hence it may be disabled by removing the resistor connected to the power supply rail.

Finally, the PIC processor needs to be able to time a ramp voltage created by a current source driving a capacitor. This is the capacitor connected to the CDAC input. When the program first starts to operate, it calibrates this slope. If it finds that it cannot, because the value of the capacitor connected to CDAC is wrong, it will display 'CDAC TOO LOW' or 'CDAC TOO HIGH', as appropriate.

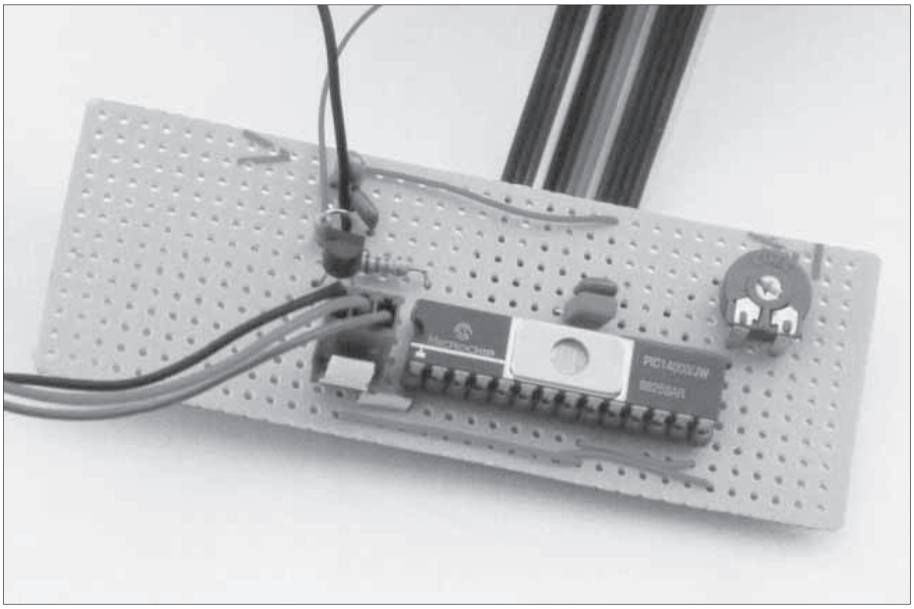


The finished article. The power meter in use.

The detailed circuit comprises a 5V regulator, the PIC processor, a trimmer pot, five capacitors and three resistors (and an LCD display of course!).

You cannot get a much simpler computer. There isn't even a clock - the PIC does that itself internally, which reduces RF emissions.

The LCD display is any of the alphanumeric displays containing the Hitachi HD44870 LCD controller family. These are available for about £12 from Farnell or Maplin, but may also be picked up very cheaply from rallies or firms selling old stock lines. In general these have a 14-pin single in line or



The display board.

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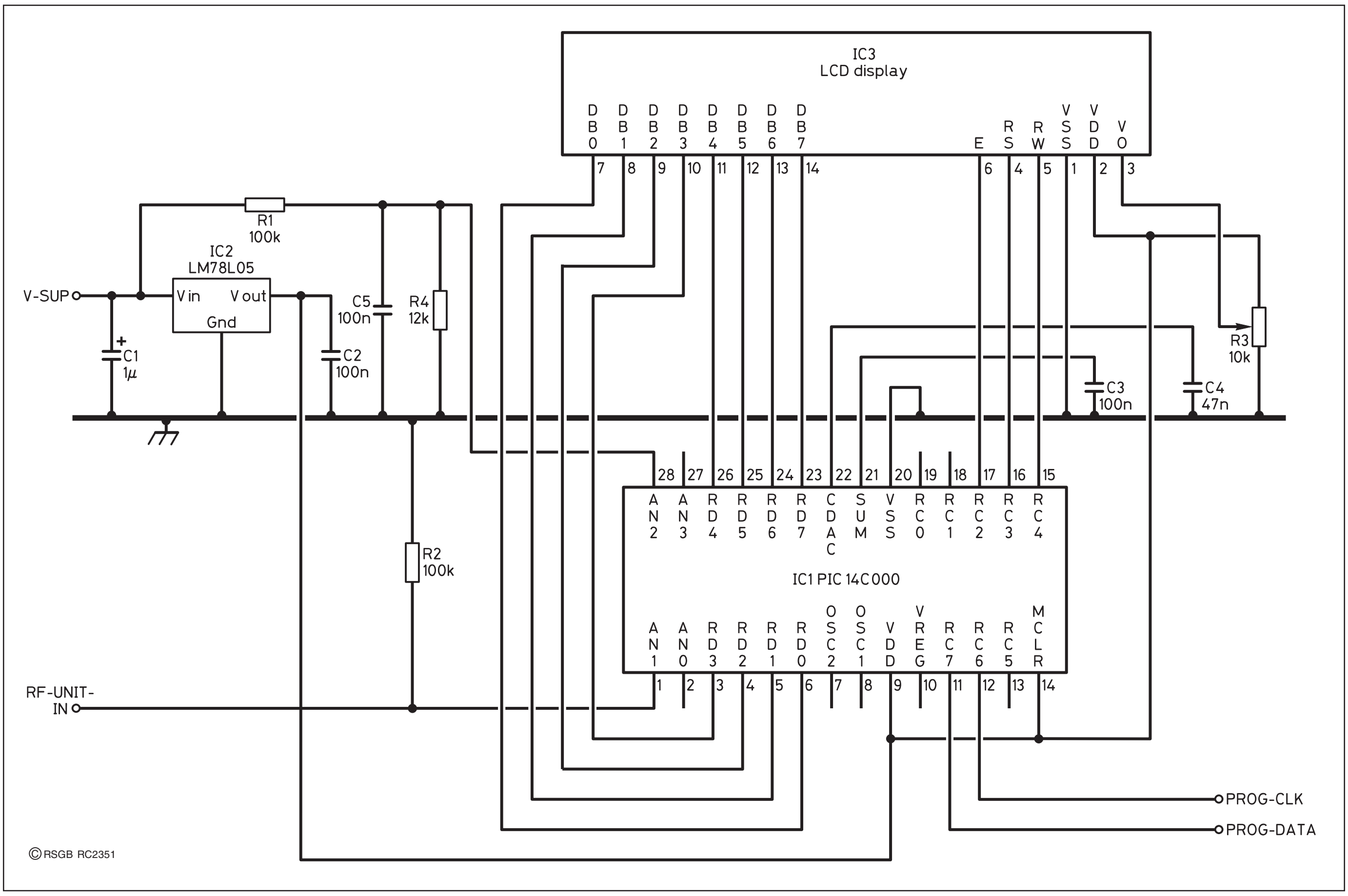


Fig 9: Display unit circuit diagram. Note that the potentiometer connected to the LCD controls contrast. For the Vikay display, connect it only to ground and the LCD - leave the connection to 5V open. Omit R1 to disable the 'low battery' feature. If the the display shows only the first 8 characters, ground the OSC1 input to the PIC. Grounding RC0 and RC1 control the display range (see Table 1).

20-pin dual in-line connector pad block that is simply wired to the PIC PCB. The interface is an 8 bit data port, an enable signal, a Read/ Write signal and a Register Select Signal. The communications used is shown in **Fig 10**. My second prototype used the Vikay 216 from Maplin.

Some displays, such as the Vikay 216, split the 16 character line into two 'logical' lines of 8 characters. To cater for this, the software will drive it as a two line display if the PIC OSC1 input is grounded.

DISPLAY UNIT COMPONENTS

Resistors (all 5% unless otherwise stated)

R1, R2	100k
R3	10k miniature pot
R4	12k
Capacitors	
C1	1µF 16V Tantalum
C2, C3, C5	100nF ceramic
C4	47nF (see below)
Semiconductors	
IC1	PIC14C000
IC2	LM78L05
IC3	LCD display
Miscellaneous	
JP1	3 pin header plus link

All devices are available from Farnell.

A display such as Vikay 216 from Maplin is suggested, but any similar display will suffice.

It is preferable (but not essential) that C4 be a low voltage coefficient type, such as teflon, polypropylene or polystyrene.

The PIC processor operates from 5V, derived from a small 5V regulator. This also supplies power to the AD8307. Whilst the PIC is capable of regulating its own supply, I thought it better to provide a stable reference for the RF unit. You could use a MOSFET and eliminate the 5V regulator, but it does not seems worthwhile.

No PCB is provided for the PIC processor. It is so simple that it is easier to wire it up on a small piece of stripboard than to produce a PCB.

PROGRAMMING THE PIC

THIS IS THE only tricky bit. If you have access to a programmer that supports the PIC14C000 then the easiest way is to use that. If not, a simple interface circuit is provided in **Fig 11**.

The PIC is programmed by a serial interface consisting of clock and data. This is easily provided by a PC parallel port. However, in order to read the data as well as to write it, this needs to be a bi-directional port for the circuit shown. Be a little careful here. If you have a really old PC, chances are it is the original IBM spec port that cannot read data on the 8 data lines. If it is more modern it may have a bi-directional mode, or it may have the more recent EPP or ECP modes. These may often be switched into bi-directional mode by the BIOS. The data is written and read through bit 0 of the data bus on pin 2 of a DB25 LPT port. The select signal (pin 1 of the 25 pin parallel port connector) is used to clock the data. Pin 17 is used to switch the programming supply voltage. Pin 18 is one of many that can be used for ground. A *short* cable is constructed with a DB25 LPT connector at one end and connected to the display PCB via a small header.

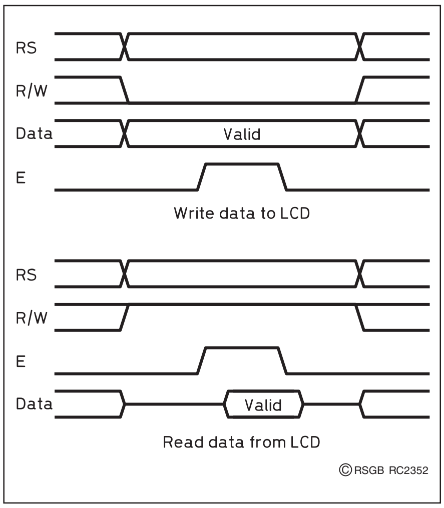


Fig 10: Communication between the PIC and LCD.

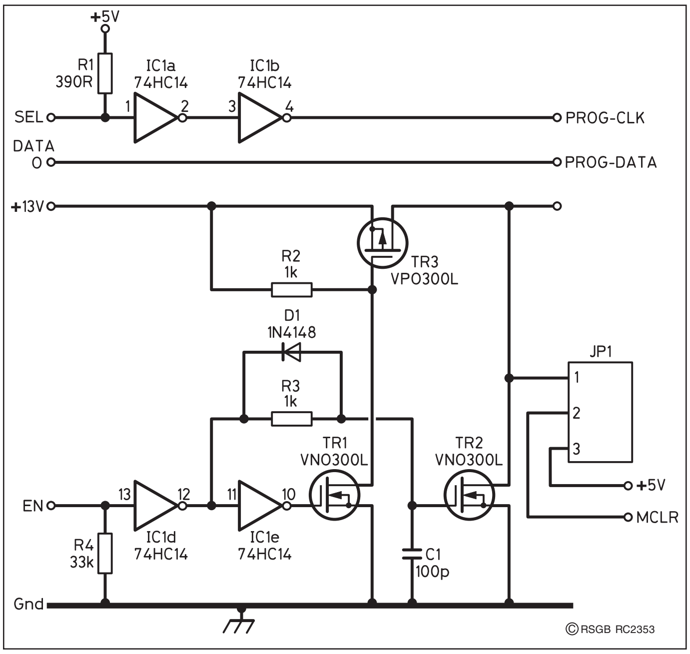


Fig 11: Circuit of the PIC programmer. Note that SEL connects to pin 1 of DB-25 LPT port. DATA0 connects to pin 2, EN connects to pin 17, and ground is connected to pin 18.

Three simple DOS programs are available to program the device. These are 'CAL-14K', 'READ-14K' and 'PROG-14K'.

It is important that they be run from DOS, *not* from within Windows (that means rebooting your PC into DOS, *not* opening a DOS box from Windows).

Programming the PIC requires a series of 100µs programming instructions. In order to deliver this accurately, the CAL-14K program is used to calibrate a delay loop. Programming also requires a 13V supply to the chip. Just to be awkward, the sequence of events needed for the PIC is as follows:

- Apply 5V to the PIC whilst holding MCLR low
- Whilst holding RC6 and RC7 low, raise MCLR to 13V in less than 8µs
- Apply sequence of load, increment, program and read instructions as required
- Drop MCLR to 0V in less than 8µs.

Full details are in the PIC14C000 programming guide [2] and datasheet [3]. The PROG-14K program takes care of the details.

In order to program the device, therefore, the circuit of Fig 11 may be added to the PIC circuit. This comprises a power MOSFET switch driven by a Schmidt inverter. It allows the PC to drive MCLR to ground or to 13V very quickly. Keep the wiring short, as it will switch the voltage on and off in times less than 50ns and 200ns respectively, and ringing may occur. The programming circuit is connected to three signals from the PC parallel port.

Full details on how to use the software are not presented here. The PIC source code, object file, PC programs (source and executables) plus guidance notes are available on the Internet from the Warrington Amateur Radio Club web site [5]. In overview though, the PC is connected by a short lead to the programmer board. The circuit is simple, and care must therefore be exercised in programming to avoid damage to the PIC. The CAL-14K program is run to determine the correct setting for a 100µs program cycle. This also has the side effect of ensuring that the signals from the PC are in a 'safe' state. This is important. The PIC is plugged in and the jumper connected to MCLR is set to connect it to the programmer circuit. The power supply is set to a supply voltage of between 13 and 13.25 volts and connected to the unit. The PROG-14K circuit is run to program the device. The supply is removed and the link reset so that, when it is next powered up, the MCLR pin is connected to the 5V supply.

RC0, RC1 open (or high)	100W FSD
RC0 grounded	10W FSD
RC1 grounded	1W FSD
RC0, RC1 grounded	1000W FSD

Table 1: Setting the power measurement range.

Each PIC14C000 is programmed by the manufacturer with a set of calibration data that is specific to it. If you use a non windowed (and therefore non erasable) component, then this is of little relevance. If you use an erasable device (the PIC14C000JW) then remember to read and save a copy of the device's specific values. These must be re-loaded into the device after erasure. This is described in detail in the notes with the program [5]. In all cases, the configuration data should not be programmed. If you get this wrong you can prevent further programming of the device. The implication of this is that the watchdog timer will be active, but the software caters for this.

CHANGING THE PROGRAM

THERE ARE TWO patch fields available which are not shown on the PIC circuit diagram. These are described in the software listings. One is used to select one of 4 different ranges. If you decide to use a different AD8307 input attenuator to achieve a different range for the meter, this field allows the range to be altered so that the maximum DC input corresponds to a display of +60dBm (1kW) to +30dBm (1W) in 10dB steps. The means to do this is shown in **Table 1**.

The second patch field allows reconfiguration to suit different LCD displays. A display may only have a single display line, but logically it may be split into two lines. An example of such a display is the Vikay 216 from Maplin. With such a display, the first and second 8 characters are separate 'lines'. The PIC must therefore select two line mode and offset the data addresses by 40 for the second half of the line. This is configured by pulling the OSC1 input low. For other displays, such as the Hitachi 16 character modules, this is not needed.

If you want to make a more radical change, then the PIC source is provided. This may be assembled using the Microchip assembler (current version is V02.20 available on free download from their web site) and to debug the code requires MPLAB. This is also available free from Microchip web site.

One such modification might be to make it into an RF voltmeter, and display not power but volts.

DEBUGGING THE DISPLAY

THE DISPLAY UNIT is simple enough to be easy to debug. The main problem is the connection of the PIC to the display. If when you power it up there is nothing shown on the display, and altering the LCD contrast trimmer R3 does nothing, connect an oscilloscope to RC5. You should find that this is normally low, and pulses quickly high after every set of readings (about 3 times a second). If you find it stuck at 1, getting set low temporarily every 2 and a half seconds, or simply low apart from a brief pulse every 2.5 seconds, then it is likely that the PIC is failing to talk to the display properly and is being reset by the watchdog timer every 2.5 seconds.

The way that it talks to the display controller is as follows:

During initialisation, it resets the control-

PIC PROGRAMMER COMPONENTS

Resistors (all 5%, unless otherwise stated)

R1	390R, 0.5W
R2, R3	1k
R4	33k
Capacitor	
C1	100pF ceramic
Semiconductors	
D1	1N4148
TR1, TR2	VN0300L
TR3	VP0300L
IC 1	74HC14

The MOSFETS are available in a variety of packages (TO-92e, E-line, etc). Any will suffice. They are available from Farnell.

ler. This is achieved by initially sending commands to the controller, without waiting to see if the controller is ready. Then, once it believes that the controller is reset, it sends commands and data by first checking the 'ready' bit. This involves reading the ready flag from the controller, by performing a control data read and checking data bit 7. Check to see if it is stuck at this stage (see Fig 10).

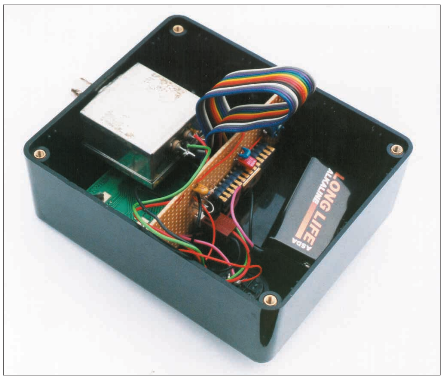
When performing normally, RC5 is set low when the PIC is performing analogue conversions and set high when it is performing calculations and sending data to the LCD. To check out the display range, you should find that it shows -50dBm when AN1 is grounded.

FINALE

YOU MAY FIND that, having calibrated the RF unit and connected it to the digital display, it does not show quite the right result. To calibrate it, apply the RF unit and supply it with 0dBm as before. It should read correctly. If not, a slight tweak to the pots may be needed. I am afraid this is iterative.

Do *not* get too hung up about the absolute accuracy of the unit. Don't forget that it is showing a display outrageously beyond its accuracy. It is at best accurate to 1dB and will not be perfect across the frequency range.

Power supply is fairly easy to arrange.



In a completed sample, the display board can just be seen under the RF unit.

Anything that keeps the 5V regulator happy is fine - such as a PP3 or 12V supply. If your LCD display has an LED backlight though, be careful about how you supply it - or you will fry the regulator (it took me ages to realise what was causing the horrible smell in my first prototype).

The tail off that can be seen in the frequency response is largely due to the input capacitance of about 1.5pF interacting with the high values of input attenuator. Any additional strays introduced by the construction may make this worse. On the other hand it may make it better - but on the whole keep the wiring short and simple. In theory it would be possible to match-out the capacitance by a much smaller value in parallel with the 33k resistor, but this is very hard to do (the value needs to be about 0.2pF). I had a try and gave up. Also note that if you change the input resistor to 100k you make the effects worse and if you lower it the effect is reduced slightly. The main determining factor is the 1.5k resistor. If you produce a better matching circuit for the range 0.1 to 500MHz, let me know. One such approach suggested by G3PTU, is to replace the resistive attenuator by a direct coupler, terminating the input with a 50Ω resistor.

Finally, it would be possible to compensate by getting the PIC to measure the input frequency and apply an offset automatically. The measurement only needs to be approximate, but the complexity is not really justified. Maybe, if the AD8307 gave an RF output from its log amp, I would have done it - but a device with that much gain and an RF output would almost certainly be unstable. ♦

REFERENCES

[2] Microchip PIC14C000 programming guide, available from http://www.microchip.com

[3] Microchip PIC14C000 data sheet, 1996, available from http://www.microchip.com

[4] Microchip application note 624, available from www.microchip.com

[5] http://www.warc.org.uk